

Appendix 5.7-J

Bird Monitoring Using the Mobile Avian Radar System (MARS) Nantucket Sound, Massachusetts

BIRD MONITORING USING THE MOBILE AVIAN RADAR SYSTEM (MARS) NANTUCKET SOUND, MASSACHUSETTS

Prepared for:

**Cape Wind Associates
75 Arlington Street
Boston, MA 02116**

Prepared by:

**Geo-Marine, Inc.
550 East 15th Street
Plano, TX 75074**

February 2004

TABLE OF CONTENTS

	<u>Page</u>
1.0 INTRODUCTION.....	1
1.1 Purpose	1
1.2 Study Area and Period	1
2.0 RADAR METHODOLOGY.....	2
2.1 Radar Ornithology	3
2.2 Mobile Avian Radar System (MARS)	3
2.2.1 VerCat Radar.....	3
2.2.2 TracScan Radar	4
2.2.3 3-D Coverage and Characteristics	5
2.3 MARS Data Processing.....	5
2.4 Radar Study Method and Limitations	6
3.0 RADAR DATA ANALYSIS	6
3.1 Detections vs. Tracks	6
3.2 Data Content.....	7
3.2.1 VerCat.....	7
3.2.2 TracScan	8
4.0 RESULTS.....	8
4.1 Operational Hours	8
4.2 Bird Target Counting	11
4.3 VerCat Data	11
4.4 TracScan Data.....	16
4.5 Field Observations.....	23

LIST OF FIGURES

<u>Figure No.</u>	<u>Page</u>
1. Locations of Nantucket Sound Radar Survey Sites	1
2a. MARS Study Site: Spring on the Amelia Mary.....	2
2b. MARS Study Site: Fall on Cape Poge	2
3. VerCat Coverage Pattern.....	4
4. TracScan Coverage Pattern	5
5. Slow Bird Heading Distribution, Spring	19
6. Fast Bird Heading Distribution, Spring.....	20
7. Slow Bird Heading Distribution, Fall.....	21
8. Fast Bird Heading Distribution, Fall	22

LIST OF TABLES

<u>Table No.</u>	<u>Page</u>
1. MARS Radar Parameters	3
2. Study Data	7
3. VerCat Size Classification.....	7
4. Total Hours of Radar Data Recorded by MARS, by Weather Type, During Spring and Fall	8
5. Daily Summary, by Weather, of VerCat Radar Monitoring	9
6. Daily Summary, by Weather, of TracScan Radar Monitoring	10
7. Altitude Distribution (above VerCat) by Size Class, Spring and Fall	12
8. Altitude Distribution (AMSL) by Size Class, Spring and Fall.....	13
9. VerCat Count Distribution by Weather, Spring	14
10. VerCat Count Distribution by Weather, Fall.....	15
11. Bird Counts in Various Weather Conditions, Spring.....	17
12. Bird Counts in Various Weather Conditions, Fall.....	18
13. Bird Species Observed in Horseshoe Shoal During Spring Study Period.....	23
14. Bird Species Observed on Cape Poge and/or Nantucket Sound During Fall Study Period.....	23

LIST OF ACRONYMS AND ABBREVIATIONS

AGL	Above Ground Level
AMSL	Above Mean Sea Level
cm	Centimeter(s)
ft	feet
GMI	Geo-Marine, Inc.
GMT	Greenwich Mean Time
Hz	Hertz
ID	Identification
km	kilometer(s)
kts	knots
kW	Kilowatts
m	meter(s)
MARS	Mobile Avian Radar System
MHz	MegaHertz
nmi	Nautical mile(s)
nsec	nanosecond(s)
PRF	Pulse Repetition Frequency
UMT	Universal Mean Time
Z	Zulu time

1.0 INTRODUCTION

1.1 Purpose

Horseshoe Shoal is located in Nantucket Sound between Cape Cod and Martha's Vineyard (**Figure 1**). The general area of Nantucket Sound and its surrounding waters and landmasses provides breeding, migratory, and wintering habitat for a number of migratory bird species, including the federally endangered Piping Plover (*Charadrius melodus*) and Roseate Tern (*Sterna dougallii*). The area is also an important migration staging area for many species of birds. This study was conducted to provide information and data to be used in an Environmental Impact Statement that will assess the impact of constructing and operating power-generating wind turbines at Horseshoe Shoal, in the center of Nantucket Sound. The purpose of this radar study was to determine bird use, particularly migrants, of the Horseshoe Shoal area of Nantucket Sound; specifically, how use varies with altitude above the water, weather conditions, time of day, and season.

1.2 Study Area and Period

Bird location data were collected by the Geo-Marine Inc. (GMI) Mobile Avian Radar System (MARS) from May 8 through June 7 and September 3 through September 30, 2002. Data collection periods were chosen based upon spring and fall migrations on the Atlantic flyway. The MARS radars were operated continuously during the study periods; however brief interruptions in operation occurred occasionally due to disruptions in power supply, system troubleshooting, and certain weather conditions, which are described below.

In the spring, the MARS was deployed on the Amelia Mary (a jack-up lift boat) in Nantucket Sound, on the southern edge of Horseshoe Shoal (41 28.167N/-70 20.771W) approximately 15 feet (4.6 m) above mean sea level (AMSL) (**Figure 2a**). During the fall study period, the MARS was located at Cape Poge on the northeastern tip of Martha's Vineyard (41 25.212N/-70 27.138W). At this location the MARS was located on a cliff approximately 28 feet (8.5 m) AMSL (**Figure 2b**).

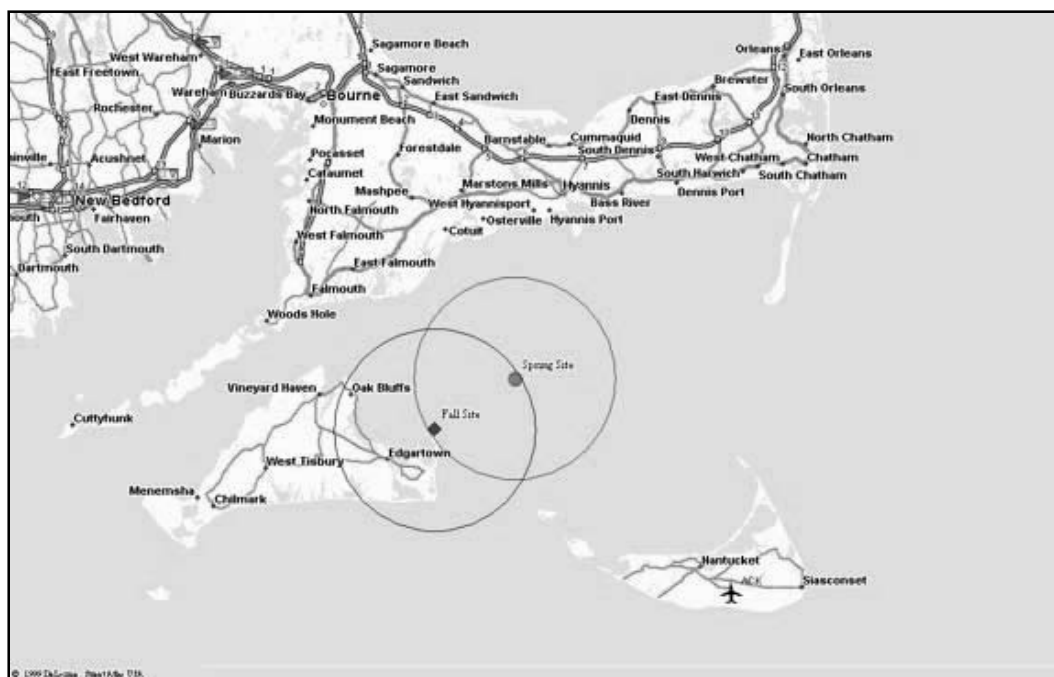


Figure 1. Locations of Nantucket Sound Radar Survey Sites.



Figure 2a. MARS Study Site: Spring on the Amelia Mary.



Figure 2b. MARS Study Site: Fall on Cape Poge.

2.0 RADAR METHODOLOGY

The MARS was employed to monitor bird activities in the study area (Figure 1). GMI developed the MARS to monitor bird activities, usually around airfields, to support efforts to reduce bird-aircraft collisions. The MARS consists of two radars:

- TracScan, which measures bird activity in a horizontal plane (range, direction, speed)
- VerCat, which measures bird activity in a vertical plane (altitude and downrange).

The MARS uses specialized software to automatically process radar data to detect and record bird activity. This allows for a characterization of bird activities in three dimensional space 24 hours per day. The MARS is able to identify birds by size class; however, it does not differentiate among taxa.

2.1 Radar Ornithology

Radar is an acronym for Radio Detection And Ranging. All radars function on the same principle: transmit a radio signal, and then listen for the signals that reflect back. The farther away a target is, the longer it will take for a signal to return and the weaker that signal will be on arrival.

Practically any object will reflect radar signals; how strong those reflections are depend upon what an object consists of and the wavelength of the radar signal. Metals (i.e., an airplane) reflect radar energy strongly; salt water and land reflect weakly. From radar's perspective, a bird is nothing more than a mass of salt water moving around. Bird radar returns (or bird reflectivity) are small relative to airplanes or boats; in practice, this means that radars detect birds for short ranges. Empirical evidence shows that bird reflectivity is generally related to bird mass. Additionally, bird reflectivity is stronger for S-band radars (10 centimeter (cm) wavelengths) than for X-band radars (3 cm wavelengths).

Reflections from the ground or the sea are seen by the radar as clutter. The clutter returns are of similar strength as bird returns. Fortunately, birds move while clutter remains essentially fixed and the MARS system is setup to eliminate clutter and stationary objects.

2.2 Mobile Avian Radar System (MARS)

The fundamental operation of VerCat and TracScan are the same, only the characteristics change. Both use commercial Marine radars to transmit and listen for returns. The radar transmits many pulses a second (pulse repetition frequency, PRF). A pulse is transmitted over a very short time (the pulselength); then the radar listens until it is time to transmit the next pulse. Combinations of PRF and pulselength are fixed by radar manufacturers.

The main radar parameters for VerCat and TracScan as mentioned are summarized in Table 1.

Table 1. MARS Radar Parameters

Radar Parameters	VerCat (FR-1525)	TracScan (FR-1420)
Transmit Power	25 kW	30 kW
Transmit Frequency	9415 MHz	3040 MHz
Transmit Pulselength	70 nanoseconds (nsec)	70 nsec
Pulse Repetition Frequency	3000 Hz	3000 Hz
Azimuth Beamwidth	20 degrees	3 degrees
Elevation Beamwidth	1 degrees	25 degrees
Maximum Study Range	0.75 nautical mile (nmi) downrange (1.4 km) 1.5 nmi (9000 ft) altitude	4 nmi (7.4 km)
Range Resolution	70 ft (21 m)	70 ft (21 m)
Antenna Polarization	Vertical	Horizontal

2.2.1 VerCat Radar

The GMI VerCat radar system uses a commercial Marine X-band radar (Furuno model FR-1525), transmitting 25 kilowatts (kW) at a frequency of 9410 MHz (3.2 cm wavelength). The MARS mounts this radar to scan in a vertical plane, from the horizon to the sky to the opposite horizon to the ground and so

forth. The radar scans at 24 rpm, making one full rotation of 360 degrees every 2.5 seconds. The signal is transmitted (and returns are received) through the VerCat X-band antenna. This 8-ft long “bar” antenna focuses the signals into a fan-shaped beam, which is 1 degree wide in the scanning plane and extends 10 degrees to either side of the scanning plane (**Figure 3**).

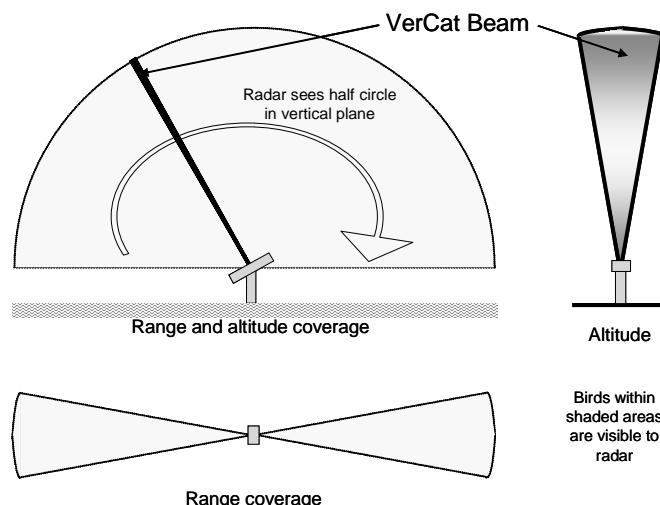


Figure 3. VerCat Coverage Pattern.

While the antenna is pointed at the ground, no signal is transmitted. Otherwise, the VerCat radar transmits for 70 nanoseconds (nsec), then listens for returns. This cycle is repeated 3000 times a second. In essence, VerCat transmits 21 pulses for every degree its radar beam sees.

Radar antennas are designed to operate scanning horizontally, not vertically. When the antenna is pointing at the sky, some energy leaks out the backside of the antenna and bounces off the ground (or sea). GMI has fitted the VerCat antenna with a custom-designed shield to minimize the impact of the ground-bounce clutter.

The VerCat scan pattern results in a “virtual mist net.” In this, the radar data determines target altitude and downrange distance from the radar site. With its 1 degree beam width, after processing by GMI algorithms, VerCat also returns estimates of target size. Targets flying along the axis of the VerCat radar can be tracked with speed estimates but targets crossing through the VerCat radar beam appear stationary. As a consequence, VerCat is not the best radar to determine bird speeds and headings.

Due to the nature of X-band signal propagation in the atmosphere, and the generally smaller returns of birds in X-band, the typical operational range is limited to 0.75 nautical miles (nmi) downrange and 1.5 nmi of altitude. Furthermore, X-band is quite sensitive to moisture; precipitation degrades the performance of VerCat. Finally, the version of the MARS software used for this study referred an altitude of 0 feet to the center of the radar scanner unit (in practice, the VerCat scanner sits 8 ft (2.4 m) above ground level (AGL) of the MARS unit).

2.2.2 TracScan Radar

The GMI TracScan radar system uses a commercial Marine S-band radar (Furuno model FR-1420), transmitting 30 kilowatts (kW) at a frequency of 3040 MHz (9.8 cm wavelength). This radar scans a horizontal plane along the horizon. The radar scans at 24 rpm, making one full rotation of 360 degrees every 2.5 seconds. The signal is transmitted (and returns are received) through the TracScan S-band antenna. This 9-ft (2.7 m) long “bar” antenna focuses the signals into a fan-shaped beam, which is 3 degrees wide in the scanning plane and extends 12.5 degrees above and below the scanning plane. The

antenna mount was shimmed to provide another 3 degrees of elevation; in operation, the fan beam extended 15.5 degrees above the horizon, and 9.5 degrees below the horizon (**Figure 4**).

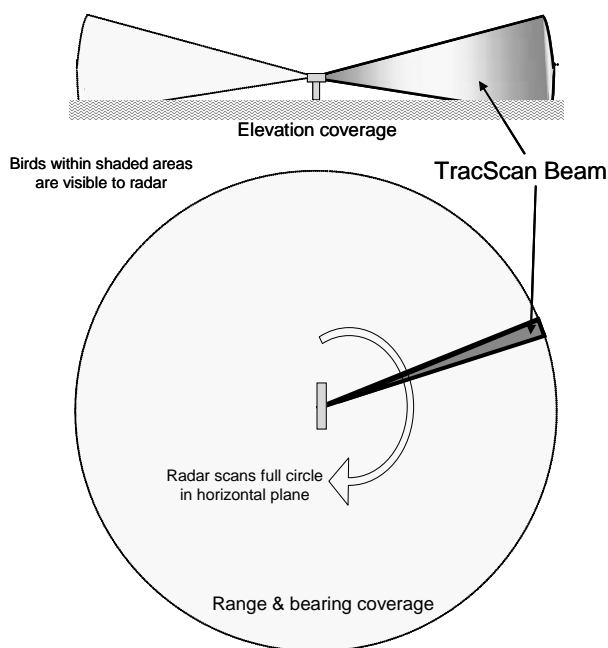


Figure 4. TracScan Coverage Pattern.

The TracScan radar transmits for 70 nsec, then listens for returns. This cycle is repeated 3000 times a second. In essence, TracScan transmits 21 pulses for every degree its radar beam sees.

TracScan data is used to determine target position (range & bearing), speed and heading. With its relatively wide beam width of 3 degrees, TracScan is not the best radar to determine target size. S-band signals propagate very well in the atmosphere; considering the generally “strong” returns of birds in S-band, TracScan’s operational detection range for large birds (i.e., geese) is over 10 nmi (18.5 km).

For this radar study, TracScan was operated on its 4 nmi (7.4 km) mode. This is the longest range possible for TracScan without changing to a longer transmit pulse length and suffering reduced spatial resolution.

2.2.3 3-D Coverage and Characteristics

Concurrent radar coverage occurs in the two cone-shaped intersections of the VerCat and TracScan ranges. As such, targets detected by one radar are not necessarily detected by the other, therefore making it difficult to make correlations between the two. All data contained in this report were derived from either the VerCat or the TracScan radar.

2.3 MARS Data Processing

GMI takes the radar returns during the listening period and processes them through a specialized high-resolution radar capture card. This card provides radar resolution at least 256 times that of typical commercial radars. GMI-proprietary MARS software processes this high-resolution data to generate dynamic maps of clutter, identify and exploit the small differences between clutter and bird targets, and archive the detections for post-study analysis. All this occurs in real-time, that is, in less time than it takes

to complete one full scan of the radar. Data associated with bird targets are written to a Microsoft Access database that can be queried during post-study processing.

2.4 Radar Study Method and Limitations

Radar is a powerful tool to monitor bird activity at night, or during poor weather. Yet, it has its basic limitations. Compared to the human eye, radar is a coarse sensor. There is no easy or practical way for off-the-shelf radars to determine the difference between White Wing Scotors or Double-Crested Cormorants, let alone the difference between Ring-Billed Gulls and Laughing Gulls. The best that can be done is determining a broad class of bird sizes (small, medium, and large) that can be distinguished by radar echo and bird mass to those size classes.

The other limitation on radar is due to the combination of antenna beamwidth and transmit pulse. Any targets angularly separated by less than the antenna beamwidth cannot be resolved separately. Likewise, any targets closer to each other than the range resolution of the radar will not appear as separate targets. Size estimates are managed using VerCat, which has the narrower of the radar beamwidths. TracScan, with its superior range to VerCat and its coverage of a large area, is used for speed and direction estimates.

Radar ornithologists and biologists operated MARS throughout the study period. The operators have a critical function at the start of the study – optimizing the radar performance to detect birds given the specifics of the monitoring environment. Afterwards, MARS can operate unattended (save for the necessary refueling and maintenance times); the operators provide the benefit of knowing bird behavior in the wild and also how bird behavior appears on radar. This allows them to adjust MARS settings if needed, to maximize the ability to detect and track birds.

Human observers in the field, in addition to the radar operators, help confirm that radar is seeing birds over its entire viewing area. During the spring and fall monitoring seasons, GMI and other observers conducted visual surveys for birds from various locations within the study area. These observations were used to characterize the birds typical of the study area during the monitoring periods. Additionally, field observations of “extraordinary events” such as large groups of migrating birds were noted.

3.0 RADAR DATA ANALYSIS

3.1 Detections vs. Tracks

A detection is any return of significant reflectivity. This is an obvious process where there would normally be clear air, i.e., no clutter. Beyond that, VerCat and TracScan use proprietary algorithms to detect real signals in presence of background clutter. A database of detections becomes large rapidly. In addition to a location of detection, detections have other metrics such as strength, size and shape, in clear air or clutter, and so on.

The tracking process takes a time-sequence of detections and correlates them into a track. Tracks possess characteristics such as speed and direction in addition to location; where detections only possess location. MARS tracks on a 3-of-4 basis; that is, if there are 3 or 4 points that correlate together across 4 scans, a track exists. The track remains in existence until only 2 points correlate across 4 scans; at this point the track vanishes.

A track is assigned a unique ID. For archive purposes, each track for a radar scan is saved to database with its metrics, including the location of the last 4 points. All tracks existing during a given scan are archived; any uncorrelated detections for a given scan are discarded. This method reduces the overall size of a database by having many fewer entries, even though extra data fields of track quality, speed, heading and previous history points have been added to the database.

The VerCat data was post-processed at the GMI Avian Research Lab in Panama City during the months of April – May, 2003, to generate correlated bird tracks. The TracScan data required no additional post-processing to generate correlated bird tracks.

3.2 Data Content

The following data elements are available for the study analysis.

Table 2. Study Data

Seasons:	Spring: May 8, 2002 –June 7, 2002 Fall: Sep 3, 2002 –Sep 30, 2002
Time:	Radar data is recorded under Universal Mean Time (UMT), also known as Greenwich Mean Time (GMT) or Zulu (Z) time. Daytime is 30 minutes before sunrise until 30 minutes after sunset. An average sunset and sunrise
Day	Spring: 08:38-00:43Z, Fall: 09:39-23:43Z
Night:	Spring: 00:44Z – 08:37Z. Fall: 23:44Z – 09:38Z.
Weather:	ESS provided a master weather database to GMI. The weather types are categorized as Clear, Rain, Mist and Fog.
VerCat:	Altitude and Size
TracScan:	Heading and Speed

3.2.1 VerCat

VerCat targets were recorded and sized based on radar images of typical bird masses. Target sizes in the database correspond to the following bird class range in **Table 3**.

Table 3. VerCat Size Classification

Target Class	Target Code	Mass
Small	1	< 80 grams
Medium	2	80 – 800 grams
Large	3	> 800 grams
Flock	4	Significantly above 800 grams

VerCat detects objects in the upper hemisphere, 180° above itself. Birds that flew below the radar were not recorded. The VerCat scanner and antenna are mounted 8 feet (2.4 m) above ground level of the MARS unit. Therefore, in the spring when MARS was deployed on the Amelia Mary liftboat, 15 feet (4.6 m) AMSL, an altitude of 0 ft in the VerCat database corresponds to 23 feet (7 m) in the real world. In the fall when MARS was deployed at Cape Pogue at 28 feet (8.5 m) AMSL, VerCat data begins at 36 feet (11 m) AMSL.

VerCat is particularly sensitive to rain; unfortunately, rain when detected appears similar to bird detections. Rain is difficult to remove via clutter processing methods; also, rain produces more clutter at

X-band than can be removed from the data during processing of data. This makes detection of targets in rain (for X-band only) unreliable.

3.2.2 TracScan

TracScan detects, tracks, and records the speed, direction of movement, and position across two-dimensional space. Speeds of bird targets were recorded as fast (>27 knots 50 km/h) or slow (<27 knots); this classification is intended to serve to distinguish between migrant and residential birds. Being an S-band system, and operating on its 4 nmi (7.4 km) mode, TracScan operation for this project was not dramatically affected by rain.

4.0 RESULTS

4.1 Operational Hours

Table 4 contains the number of hours the VerCat and TracScan radars were in operation during the spring and fall study periods, categorized by weather. **Table 5** and **Table 6** have day-by-day summaries of operational time.

Table 4. Total Hours of Radar Data Recorded by MARS, by Weather Type, During Spring and Fall

VerCat Total Survey Hours					TracScan Total Survey Hours				
Weather	Spring Day	Spring Night	Fall Day	Fall Night	Weather	Spring Day	Spring Night	Fall Day	Fall Night
Clear	267.18	103.04	205.57	136.07	Clear	240.2	92.47	198.33	125.42
Fog	23.87	20.8	10.84	24.64	Fog	17.82	13.53	7.84	18.37
Rain	7.92	14	28.58	12.42	Rain	25.62	15.26	28.41	11.72
Mist	31.01	27.42	19.33	18.4	Mist	27.36	24.93	17.67	21.6
Total	329.98	165.26	264.32	191.53	Total	311	146.19	252.25	177.11

MARS session tables hold information on general radar operation. These were initially queried to find when the radars were operating for a given session. Using that session information, all the tracks in a session were queried to find the first and last reported tracks. The span of time was correlated against the hourly weather database provided by ESS Group Inc. The results are recorded in tables as fractional hours (i.e., 0.017 is 1 minute, 0.25 is 15 minutes, etc).

Table 5. Daily Summary, by Weather, of VerCat Radar Monitoring

VerCat		Spring Day					Spring Night					Total Hours Observed
Date		Hours Clear	Hours Fog	Hours* Rain	Hours Mist	Hours Observed	Hours Clear	Hours Fog	Hours* Rain	Hours Mist	Hours Observed	
5/8/2002		14.53	0	0	0	14.53	5.93	0	0	0	5.93	20.46
5/9/2002		11.32	0	0	0	11.32	4.63	2	0	1.1	7.73	19.05
5/10/2002		4.57	0	0	0	4.57	1	0	2.37	1	4.37	8.94
5/11/2002		0	0	0	0	0	0	0	0	0	0	0
5/12/2002		0	0	0	0	0	0	0	0	0	0	0
5/13/2002		0	0	1.65	0	1.65	2.47	0	0	0	2.47	4.12
5/14/2002		4.03	0	0	2.37	6.4	0	0	3	1.63	4.63	11.03
5/15/2002		1.03	0	0	0	1.03	3.27	0	0	0	3.27	4.3
5/16/2002		15.3	0	0	0	15.3	7.9	0	0	0	7.9	23.2
5/17/2002		11.1	0	1.95	3	16.05	5.9	0	2	0	7.9	23.95
5/18/2002		0	0	2.32	0	2.32	0	0	4.63	0	4.63	6.95
5/19/2002		0	0	0	0	0	0	0	0	0	0	0
5/20/2002		7.1	0	0	0	7.1	2.05	0	0	0	2.05	9.15
5/21/2003		14.17	0	0	0	14.17	7.73	0	0	0	7.73	21.9
5/22/2002		15.47	0	0	0	15.47	7.9	0	0	0	7.9	23.37
5/23/2002		15.6	0	0	0	15.6	7.9	0	0	0	7.9	23.5
5/24/2002		15.12	0	0	0	15.12	4.63	0	0	0	4.63	19.75
5/25/2002		8.05	0	0	0	8.05	3.27	0	0	0	3.27	11.32
5/26/2002		14.98	0	1	0	15.98	5.9	1	0	1	7.9	23.88
5/27/2002		8	4.37	0	3.48	15.85	0	3.63	0	4.27	7.9	23.75
5/28/2002		9	4	0	2.68	15.68	0	0	0	7.9	7.9	23.58
5/29/2002		9	3.52	0	3.37	15.89	0	3.27	0	4.63	7.9	23.79
5/30/2002		4	8.45	0	3.37	15.82	0	7.27	0	0.63	7.9	23.72
5/31/2002		9.73	2.53	0	3	15.26	1.27	3.63	2	1	7.9	23.16
6/1/2002		13.73	1	0	1.37	16.1	4.27	0	0	3.63	7.9	24
6/2/2002		13.58	0	0	1	14.58	7.9	0	0	0	7.9	22.48
6/3/2002		16.02	0	0	0	16.02	7.22	0	0	0	7.22	23.24
6/4/2002		15.18	0	0	0	15.18	4.63	0	0	0	4.63	19.81
6/5/2002		9.72	0	0	0	9.72	3.27	0	0	0	3.27	12.99
6/6/2002		6.85	0	1	7.37	15.22	4	0	0	0.63	4.63	19.85
6/7/2002		0	0	0	0	0	0	0	0	0	0	0
Total		267.18	23.87	7.92	31.01	329.98	103.04	20.8	14	27.42	165.26	495.24

VerCat		Fall Day					Fall Night					Total Hours Observed
Date		Hours Clear	Hours Fog	Hours* Rain	Hours Mist	Hours Observed	Hours Clear	Hours Fog	Hours* Rain	Hours Mist	Hours Observed	
9/3/2002		1	0	0.17	2.73	3.9	1	0	0	3.12	4.12	8.02
9/4/2002		5.78	2.08	0	4.07	11.93	2	5.42	0	2	9.42	21.35
9/5/2002		11.4	0	0	0	11.4	7.52	0	0	0	7.52	18.92
9/6/2002		0	0	0	0	0	3.32	0	0	0	3.32	3.32
9/7/2002		12.08	1.35	0	0	13.43	4.2	3.65	0	2	9.85	23.28
9/8/2002		4.22	0.35	0	0	4.57	3.57	4.65	0	1	9.22	13.79
9/9/2002		12.12	0	0	0	12.12	9.92	0	0	0	9.92	22.04
9/10/2002		5	5.33	0	3	13.33	5	4.65	0	0	9.65	22.98
9/11/2002		3.98	0	3.35	0	7.33	4.17	4	0.65	1	9.82	17.15
9/12/2002		12.68	0	0	0	12.68	9.25	0	0	0	9.25	21.93
9/13/2002		13.6	0	0	0	13.6	7.97	0	0	0	7.97	21.57
9/14/2002		0	0	0	0	0	2.17	0	0	0	2.17	2.17
9/15/2002		9.37	0	0.92	1	11.29	5	0	1.47	0	6.47	17.76
9/16/2002		0.48	0	6.72	4	11.2	0.27	1	0	3	4.27	15.47
9/17/2002		12.8	0	0	0	12.8	3.65	1	0	1	5.65	18.45
9/18/2002		9.15	0	0	0	9.15	4.27	0	0	0	4.27	13.42
9/19/2002		13.48	0	0	0.35	13.83	4.88	0	0	2.65	7.53	21.36
9/20/2002		0	0	0	0	0	0	0	0	0	0	0
9/21/2002		0	0	0	0	0	0	0	0	0	0	0
9/22/2002		0	0	0	0	0	0	0	0	0	0	0
9/23/2002		6.63	0	1	0	7.63	4.07	0	0	0	4.07	11.7
9/24/2002		0	0	9.35	3.18	12.53	8.53	0	0.65	0	9.18	21.71
9/25/2002		12.12	0	0	0	12.12	9.73	0	0	0	9.73	21.85
9/26/2002		11.85	0	2	0	13.85	5.65	0	4	0	9.65	23.5
9/27/2002		6	1.73	5.07	1	13.8	2	0.27	5.65	1.63	9.55	23.35
9/28/2002		13.72	0	0	0	13.72	8.78	0	0	1	9.78	23.5
9/29/2002		14.08	0	0	0	14.08	9.23	0	0	0	9.23	23.31
9/30/2002		14.03	0	0	0	14.03	9.92	0	0	0	9.92	23.95
Total		205.57	10.84	28.58	19.33	264.32	136.07	24.64	12.42	18.4	191.53	455.85

* This data may not be useful due to the inability of the VerCat to identify targets during rain.

Table 6. Daily Summary, by Weather, of TracScan Radar Monitoring

TracScan	Spring Day					Spring Night					Total Hours Observed
Date	Hours Clear	Hours Fog	Hours Rain	Hours Mist	Hours Observed	Hours Clear	Hours Fog	Hours Rain	Hours Mist	Hours Observed	
5/8/2002	14.93	0	0	0	14.93	5.9	0	0	0	5.9	20.83
5/9/2002	4.9	0	0	0	4.9	4.63	2	0	1.22	7.85	12.75
5/10/2002	15.57	0	0.37	0	15.94	4.27	0	2.63	1	7.9	23.84
5/11/2002	16.1	0	0	0	16.1	5.52	0	0	0	5.52	21.62
5/12/2002	0	0	0	0	0	0	0	0	0	0	0
5/13/2002	0	0	8.2	0	8.2	2.48	0	0	0	2.48	10.68
5/14/2002	11.17	0	0	2.37	13.54	2.27	0	4	1.63	7.9	21.44
5/15/2002	14.8	0	0	0	14.8	4.63	0	0	0	4.63	19.43
5/16/2002	12.7	0	0	0	12.7	3.27	0	0	0	3.27	15.97
5/17/2002	2.37	0	1.3	3	6.67	4.63	0	0	0	4.63	11.3
5/18/2002	0	0	0	0	0	0	0	0	0	0	0
5/19/2002	0	0	0	0	0	0	0	0	0	0	0
5/20/2002	10.77	0	0	0	10.77	0	0	0	0	0	10.77
5/21/2003	0	0	0	0	0	0	0	0	0	0	0
5/22/2002	8.77	0	0	0	8.77	0	0	0	0	0	8.77
5/23/2002	0	0	0	0	0	2.73	0	0	0	2.73	2.73
5/24/2002	16.08	0	0	0	16.08	7.9	0	0	0	7.9	23.98
5/25/2002	16.07	0	0	0	16.07	7.9	0	0	0	7.9	23.97
5/26/2002	15	0	1	0	16	5.9	1	0	1	7.9	23.9
5/27/2002	8	4.37	0	3.58	15.95	0	3.63	0	4.27	7.9	23.85
5/28/2002	8.52	4	0	2.67	15.19	0	0	0	7.9	7.9	23.09
5/29/2002	8.67	2.97	0	3.37	15.01	0	0	0	4.63	4.63	19.64
5/30/2002	1.33	3.13	0	2	6.46	0	3.27	0	0	3.27	9.73
5/31/2002	9.73	3.35	0	3	16.08	1.27	3.63	2	1	7.9	23.98
6/1/2002	0	0	0	0	0	0	0	0	1.65	1.65	1.65
6/2/2002	7.38	0	0	0	7.38	3.27	0	0	0	3.27	10.65
6/3/2002	16.07	0	0	0	16.07	7.9	0	0	0	7.9	23.97
6/4/2002	0.7	0	0	0	0.7	4.83	0	0	0	4.83	5.53
6/5/2002	13.97	0	2	0	15.97	7.9	0	0	0	7.9	23.87
6/6/2002	6.6	0	1	7.37	14.97	5.27	0	2	0.63	7.9	22.87
6/7/2002	0	0	11.75	0	11.75	0	0	4.63	0	4.63	16.38
Total	240.2	17.82	25.62	27.36	311	92.47	13.53	15.26	24.93	146.19	457.19

TracScan	Fall Day					Fall Night					Total Hours Observed
Date	Hours Clear	Hours Fog	Hours Rain	Hours Mist	Hours Observed	Hours Clear	Hours Fog	Hours Rain	Hours Mist	Hours Observed	
9/3/2002	0	0	0	0	0	0	0	0	0	0	0
9/4/2002	5.57	0.73	0	2	8.3	2	0.77	0	1	3.77	12.07
9/5/2002	1.27	0	0	0	1.27	5.65	0	0	0	5.65	6.92
9/6/2002	0	0	0	0	0	0	0	0	0	0	0
9/7/2002	0	0	0	0	0	0.97	1	0	2	3.97	3.97
9/8/2002	2.42	0.35	0	0	2.77	3.53	4.65	0	1	9.18	11.95
9/9/2002	11.58	0	0	0	11.58	9.92	0	0	0	9.92	21.5
9/10/2002	5	5.03	0	3	13.03	5	4.68	0	0	9.68	22.71
9/11/2002	10.73	0	3.35	0	14.08	3.88	4	0.65	1	9.53	23.61
9/12/2002	12.42	0	0	0	12.42	9.72	0	0	0	9.72	22.14
9/13/2002	13.32	0	0	0	13.32	5.65	0	0	0	5.65	18.97
9/14/2002	12.08	0	0	2	14.08	4.17	0	0	0	4.17	18.25
9/15/2002	8.28	0	0.53	1	9.81	2.93	0	0.77	0	3.7	13.51
9/16/2002	0.4	0	6.83	4	11.23	0.27	1	0	3	4.27	15.5
9/17/2002	13.53	0	0	0	13.53	4.92	1	0	4	9.92	23.45
9/18/2002	12.52	0	0	0.35	12.87	4.27	1	0	4.65	9.92	22.79
9/19/2002	11.57	0	0	0.32	11.89	4.9	0	0	2.65	7.55	19.44
9/20/2002	0	0	0	0	0	0	0	0	0	0	0
9/21/2002	0	0	0	0	0	0	0	0	0	0	0
9/22/2002	0	0	0	0	0	0	0	0	0	0	0
9/23/2002	6.53	0	1	0	7.53	4.05	0	0	0	4.05	11.58
9/24/2002	0.73	0	9.35	4	14.08	8.58	0	0.65	0	9.23	23.31
9/25/2002	11.05	0	0	0	11.05	9.18	0	0	0	9.18	20.23
9/26/2002	11.87	0	2	0	13.87	5.83	0	4	0	9.83	23.7
9/27/2002	6	1.73	5.35	1	14.08	2	0.27	5.65	1.3	9.22	23.3
9/28/2002	13.75	0	0	0	13.75	8.63	0	0	1	9.63	23.38
9/29/2002	14.08	0	0	0	14.08	9.45	0	0	0	9.45	23.53
9/30/2002	13.63	0	0	0	13.63	9.92	0	0	0	9.92	23.55
Total	198.33	7.84	28.41	17.67	252.25	125.42	18.37	11.72	21.6	177.11	429.36

Significant periods with no data recorded by either MARS radar occurred May 12 and 19 in Spring and on September 6 and 20-22 in Fall.

4.2 Bird Target Counting

A bird track is a time-space sequence of data. All the bird counting analyses require that track data be sifted into different comparison bins. Once comparison boundaries are defined, there will be instances in which a track will be present in two different bins. A simple example is the bird climbing from 95 ft (29 m) to 105 ft (32 m). In this case, the bird shows up both in a 10-100 ft (10-30 m) band and the 100 – 400 ft (30 – 122 m) band. Similar examples can be found for heading and time boundaries.

A second consideration is related to track length. The MARS software records the Track ID and information for each track it processes during a single radar scan. A track that persists for 20 scans would show up 20 times in the database; also, it will show up to 20 times in a single comparison bin. The duplicate ID's must be removed to keep counts from being inflated.

The count of birds within the radar databases uses the general process:

1. Query the MARS databases and divide all database entries into the various comparison bins (hours, headings, weather, altitude, etc).
2. After populating the comparison bins, remove all duplicate track ID's in each bin.
3. For Track IDs that show up in two separate bins (crossing an altitude boundary, crossing a heading boundary, or crossing an hour or day boundary), each bin retains an occurrence of that track.

Consequences of this process are:

- When there are more subdivisions, fewer duplicates are removed.
- Bin counts will not sum up to the same total count.
- The same data, divided and binned differently, will have different overall sums.

4.3 VerCat Data

There are two results computed from the VerCat data: altitude distribution and bird target counts against weather. The process to generate altitude distribution was:

1. Sort database into altitude bands
2. Sort altitude bands into target size bins (1=small, 2=medium, 3=large, 4=flock, 5=other)
3. Remove all duplicates from each bin

The process is commutative until duplicates are removed (i.e., sort by target then by altitude then remove duplicates and get same results); the sorting order is chosen for processing efficiency.

Table 7 shows the altitude distribution of birds by size class for data collected in the spring and fall, during the day and night. In this table, 0 ft is height of the center of the VerCat scanner unit. For spring, VerCat height was 23 ft (7 m) AMSL (8 ft (2.4 m) tower + 15 ft (4.6 m) lift boat deck); for fall, VerCat height was 36 (11 m) AMSL (8 ft (2.4 m) tower + 28 ft cliff).

Table 7. Altitude Distribution (above VerCat) by Size Class, Spring and Fall

Altitude	Target Type				
	Small	Medium	Large	Flock	Total
Spring Day					
0 - 10	29	6	4	0	39
11 - 100	10809	2676	837	539	14861
101 - 400	22611	8198	4129	2559	37497
401 - 800	6192	710	363	196	7461
801 - 1200	5436	396	113	77	6022
1201 - 1600	2715	372	36	21	3144
1601 - 3000	1872	292	68	72	2304
3001 +	329	276	216	236	1057
<i>Subtotal</i>	49993	12926	5766	3700	72385
Spring Night					
0 - 10	7	1	0	0	8
11 - 100	4327	1073	279	145	5824
101 - 400	15547	4277	1101	612	21537
401 - 800	8753	988	119	19	9879
801 - 1200	15321	2591	78	28	18018
1201 - 1600	12270	3759	72	15	16116
1601 - 3000	12218	3087	110	28	15443
3001 +	1042	426	197	189	1854
<i>Subtotal</i>	69485	16202	1956	1036	88679
Spring Total	119478	29128	7722	4736	161064
Fall Day					
0 - 10	40	21	1	2	64
11 - 100	3771	1915	713	560	6959
101 - 400	20994	7744	2240	1387	32365
401 - 800	18565	4333	1070	548	24516
801 - 1200	15042	1853	263	126	17284
1201 - 1600	11451	1311	119	62	12943
1601 - 3000	27434	5007	329	168	32938
3001 +	16587	8133	1845	929	27494
<i>Subtotal</i>	113884	30317	6580	3782	154563
Fall Night					
0 - 10	6	1	1	1	9
11 - 100	1500	661	126	95	2382
101 - 400	13926	4181	473	137	18717
401 - 800	17066	3662	438	56	21222
801 - 1200	22377	2570	269	53	25269
1201 - 1600	27322	3558	276	36	31192
1601 - 3000	55937	11610	1049	120	68716
3001 +	16332	7017	1757	556	25662
<i>Subtotal</i>	154466	33260	4389	1054	193169
Fall Total	268350	63577	10969	4836	347732

Table 8 shows the altitude distribution by height bands of interest to the proposed wind farm. For these results, 0 ft = Mean Sea Level. This ensures that the altitude bands correspond exactly with the wind farm blade heights and the airspace they move through.

Table 8. Altitude Distribution (AMSL) by Size Class. Spring and Fall

Altitude	Target Type				
	Small	Medium	Large	Flock	Total
Spring Day					
23-74	3622	1028	341	146	5137
75-417	29024	9735	4587	2922	46268
418+	15542	2033	796	606	18977
Total	48188	12796	5724	3674	70382
Spring Night					
23-74	1450	458	127	36	2071
75-417	18046	4834	1244	714	24838
418+	44549	10571	577	278	55975
Total	64045	15863	1948	1028	82884
Spring Total	112233	28659	7672	4702	153266
Fall Day					
36-74	273	133	50	52	508
75-417	23156	9104	2772	1783	36815
418+	87058	20733	3682	1881	113354
Total	110487	29970	6504	3716	150677
Fall Night					
36-74	63	29	5	3	100
75-417	14461	4527	562	226	19776
418+	134450	28408	3811	818	167487
Total	148974	32964	4378	1047	187363
Fall Total	259461	62934	10882	4763	338040

VerCat counts, as influenced by weather, were determined as follows:

1. Sort database into daily bins, subdividing into day and night
2. Sort days into weather bins (clear, fog, rain, mist)
3. Remove all duplicates from each bin.

Table 9 presents the results for spring and **Table 10** presents the results for fall.

Table 9. VerCat Count Distribution by Weather, Spring

VerCat	Spring Day					Total Number Observed
	Date	Clear	Fog	Rain	Mist	
5/8/2002	2496					2496
5/9/2002	4756					4756
5/10/2002	2102					2102
5/11/2003						0
5/12/2003						0
5/13/2002				505		505
5/14/2002	2363				1891	4254
5/15/2002	231					231
5/16/2002	5243					5243
5/17/2002	4460			701	738	5899
5/18/2002				1117		1117
5/19/2003						0
5/20/2002	1171					1171
5/21/2002	4003					4003
5/22/2002	1895					1895
5/23/2002	2313					2313
5/24/2002	2872					2872
5/25/2002	1139					1139
5/26/2002	2317			125		2442
5/27/2002	2953	564			315	3832
5/28/2002	648	200			118	966
5/29/2002	459	177			492	1128
5/30/2002	253	395			222	870
5/31/2002	717	178			244	1139
6/1/2002						0
6/2/2002	6047					6047
6/3/2002	4285					4285
6/4/2002	2728					2728
6/5/2002	2123					2123
6/6/2002	1541			469	2301	4310
6/7/2002						0
Total	59115	1514		2917	6321	69866

VerCat	Spring Night					Total Number Observed
	Date	Clear	Fog	Rain	Mist	
5/8/2002	2061					2061
5/9/2002	351	806			336	1493
5/10/2002	409			950	346	1705
5/11/2003						0
5/12/2003						0
5/13/2002	3130			99		3229
5/14/2002				1825	2495	4320
5/15/2002	2999					2999
5/16/2002	9590					9590
5/17/2002	9077			826		9903
5/18/2002				2068		2068
5/19/2003						0
5/20/2002	2358					2358
5/21/2002	5887					5887
5/22/2002	5827					5827
5/23/2002	9585					9585
5/24/2002	8068					8068
5/25/2002	1103					1103
5/26/2002	927	644			232	1801
5/27/2002			362		1051	1413
5/28/2002					647	647
5/29/2002			327		170	497
5/30/2002			382		18	400
5/31/2002	134	103	22			259
6/1/2002						0
6/2/2002	801					801
6/3/2002	1408					1408
6/4/2002	914					914
6/5/2002	1844					1844
6/6/2002	1524				538	2062
6/7/2002						0
Total	67997	2624	5790	5833		82242

VerCat	Spring Total					Total Number Observed
	Date	Clear	Fog	Rain	Mist	
5/8/2002	4557	0	0	0	0	4557
5/9/2002	5107	806	0	0	336	6249
5/10/2002	2511	0	950	346	3807	3807
5/11/2003	0	0	0	0	0	0
5/12/2003	0	0	0	0	0	0
5/13/2002	3130	0	604	0	3734	3734
5/14/2002	2363	0	1825	4386	8574	8574
5/15/2002	3230	0	0	0	3230	3230
5/16/2002	14833	0	0	0	14833	14833
5/17/2002	13537	0	1527	738	15802	15802
5/18/2002	0	0	3185	0	3185	3185
5/19/2003	0	0	0	0	0	0
5/20/2002	3529	0	0	0	3529	3529
5/21/2002	9890	0	0	0	9890	9890
5/22/2002	7122	0	0	0	7122	7122
5/23/2002	11898	0	0	0	11898	11898
5/24/2002	10940	0	0	0	10940	10940
5/25/2002	2242	0	0	0	2242	2242
5/26/2002	3244	644	125	232	4243	4243
5/27/2002	2953	926	0	1366	5245	5245
5/28/2002	648	200	0	765	1613	1613
5/29/2002	459	504	0	662	1625	1625
5/30/2002	253	777	0	240	1270	1270
5/31/2002	851	281	22	244	1398	1398
6/1/2002	0	0	0	0	0	0
6/2/2002	6848	0	0	0	6848	6848
6/3/2002	5693	0	0	0	5693	5693
6/4/2002	3642	0	0	0	3642	3642
6/5/2002	3967	0	0	0	3967	3967
6/6/2002	3065	0	469	2839	6372	6372
6/7/2002	0	0	0	0	0	0
Total	127112	4138	8707	12154	152108	152108

Table 10. VerCat Count Distribution by Weather, Fall

VerCat	Fall Day					Total Numbers Observed
	Date	Clear	Fog	Rain	Mist	
9/3/2002		89	0	23	964	1076
9/4/2002		1400	1024	0	1284	3708
9/5/2002		6362	0	0	0	6362
9/6/2002		0	0	0	0	0
9/7/2002		13144	0	0	0	13144
9/8/2002		4916	29	0	0	4944
9/9/2002		8239	0	0	0	8239
9/10/2002		3381	2779	0	1599	7759
9/11/2002		868	0	159	0	1027
9/12/2002		4834	0	0	0	4834
9/13/2002		3948	0	0	0	3948
9/14/2002		0	0	0	0	0
9/15/2002		881	0	1109	204	2194
9/16/2002		173	0	2178	312	2663
9/17/2002		7419	0	0	0	7419
9/18/2002		7694	0	0	0	7694
9/19/2002		9256	0	0	55	9311
9/20/2002		0	0	0	0	0
9/23/2002		2491	0	190	0	2681
9/24/2002		0	0	3867	2744	6611
9/25/2002		7153	0	0	0	7153
9/26/2002		7884	0	500	0	8384
9/27/2002		2478	1627	2102	334	6540
9/28/2002		8679	0	0	0	8679
9/29/2002		13909	0	0	0	13909
9/30/2002		10136	0	0	0	10136
Total		125334	5459	10128	7496	148415

VerCat	Fall Night					Total Numbers Observed
	Date	Clear	Fog	Rain	Mist	
9/3/2002		362	0	0	564	926
9/4/2002		256	1060	0	408	1724
9/5/2002		3364	0	0	0	3364
9/6/2002		7048	0	0	0	7048
9/7/2002		3556	881	0	3223	7659
9/8/2002		2563	2192	0	473	5228
9/9/2002		8032	0	0	0	8032
9/10/2002		2962	2116	0	0	5078
9/11/2002		12438	1671	1	182	14292
9/12/2002		12620	0	0	0	12620
9/13/2002		7587	0	0	0	7587
9/14/2002		931	0	0	0	931
9/15/2002		2301	0	1154	0	3455
9/16/2002		88	1210	0	3917	5213
9/17/2002		6289	670	0	1268	8226
9/18/2002		8931	0	0	0	8931
9/19/2002		3344	0	0	830	4174
9/20/2002		0	0	0	0	0
9/23/2002		11244	0	0	0	11244
9/24/2002		9142	0	290	0	9432
9/25/2002		12903	0	0	0	12903
9/26/2002		2829	0	926	0	3755
9/27/2002		57	87	2928	163	3235
9/28/2002		14597	0	0	1203	15800
9/29/2002		16678	0	0	0	16678
9/30/2002		8982	0	0	0	8982
Total		159104	9887	5299	12231	186517

VerCat	Fall Totals					Total Numbers Observed
	Date	Clear	Fog	Rain	Mist	
9/3/2002		451	0	23	1528	2002
9/4/2002		1656	2084	0	1692	5432
9/5/2002		9726	0	0	0	9726
9/6/2002		7048	0	0	0	7048
9/7/2002		16700	881	0	3223	20803
9/8/2002		7479	2221	0	473	10172
9/9/2002		16271	0	0	0	16271
9/10/2002		6343	4895	0	1599	12837
9/11/2002		13306	1671	160	182	15319
9/12/2002		17454	0	0	0	17454
9/13/2002		11535	0	0	0	11535
9/14/2002		931	0	0	0	931
9/15/2002		3182	0	2263	204	5649
9/16/2002		261	1210	2178	4229	7876
9/17/2002		13708	670	0	1268	15645
9/18/2002		16625	0	0	0	16625
9/19/2002		12600	0	0	885	13485
9/20/2002		0	0	0	0	0
9/23/2002		13735	0	190	0	13925
9/24/2002		9142	0	4157	2744	16043
9/25/2002		20056	0	0	0	20056
9/26/2002		10713	0	1426	0	12139
9/27/2002		2535	1714	5030	497	9775
9/28/2002		23276	0	0	1203	24479
9/29/2002		30587	0	0	0	30587
9/30/2002		19118	0	0	0	19118
Total		284438	15346	15427	19727	334932

4.4 TracScan Data

There are two results computed from the TracScan data: bird target counts against weather and heading distributions. The process for the bird target counts was:

1. Sort database into days and break into day and night.
2. Sort database into weather bins.
3. Sort weather bins into speed classes (slow < 27kts, fast \geq 27kts).
4. Remove all duplicates from each bin.

The process is commutative until you remove duplicates (i.e., you sort by hours then by speed, etc, then remove duplicates and get same results); sorting order is chosen for processing efficiency.

Table 11 and 12 contain the TracScan data count for the number of birds, both fast and slow, compared against the standard weather conditions. Table 11 is for spring data. Table 12 contains the counts for fall. In these tables, fast birds are defined as those traveling in excess of 27 knots; slow birds are those birds flying slower than 27 knots.

Table 11. Bird Counts in Various Weather Conditions, Spring

TracScan Target Counts, Spring Day											
Date	Clear		Fog		Mist		Rain		Total		Grand Total
	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	
5/8/2002	1373	1390	0	0	0	0	0	0	1373	1390	2763
5/9/2002	3272	1149	0	0	0	0	0	0	3272	1149	4421
5/10/2002	20464	12726	0	0	0	0	218	60	20682	12786	33468
5/11/2002	9655	1805	0	0	0	0	0	0	9655	1805	11460
5/12/2002	0	0	0	0	0	0	0	0	0	0	0
5/13/2002	0	0	0	0	0	0	6793	2023	6793	2023	8816
5/14/2002	5007	1886	0	0	2958	765	0	0	7965	2651	10616
5/15/2002	1265	365	0	0	0	0	0	0	1265	365	1630
5/16/2002	10780	3441	0	0	0	0	0	0	10780	3441	14221
5/17/2002	2549	845	0	0	2939	677	2225	692	7713	2214	9927
5/18/2002	0	0	0	0	0	0	0	0	0	0	0
5/19/2002	0	0	0	0	0	0	0	0	0	0	0
5/20/2002	22327	5575	0	0	0	0	0	0	22327	5575	27902
5/21/2002	0	0	0	0	0	0	0	0	0	0	0
5/22/2002	10707	1719	0	0	0	0	0	0	10707	1719	12426
5/23/2002	0	0	0	0	0	0	0	0	0	0	0
5/24/2002	17363	4497	0	0	0	0	0	0	17363	4497	21860
5/25/2002	15250	2934	0	0	0	0	0	0	15250	2934	18184
5/26/2002	13494	1992	0	0	0	0	1204	165	14698	2157	16855
5/27/2002	8658	4904	5555	1432	2049	1150	0	0	16262	7486	23748
5/28/2002	5006	1488	2038	1850	463	257	0	0	7507	3595	11102
5/29/2002	4602	3086	2210	1191	2897	1885	0	0	9709	6162	15871
5/30/2002	449	226	800	282	900	263	0	0	2149	771	2920
5/31/2002	1731	1014	885	644	339	271	0	0	2955	1929	4884
6/1/2002	0	0	0	0	0	0	0	0	0	0	0
6/2/2002	3988	1072	0	0	0	0	0	0	3988	1072	5060
6/3/2002	3781	1431	0	0	0	0	0	0	3781	1431	5212
6/4/2002	157	29	0	0	0	0	0	0	157	29	186
6/5/2002	9832	1709	0	0	0	0	1151	227	10983	1936	12919
6/6/2002	1018	380	0	0	3307	704	41	6	4366	1090	5456
6/7/2002	0	0	0	0	0	0	345	95	345	95	440
Total	172728	55663	11488	5399	15852	5972	11977	3268	212045	70302	282347

TracScan Target Counts, Spring Night											
Date	Clear		Fog		Mist		Rain		Total		Grand Total
	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	
5/8/2002	1133	2548	0	0	0	0	0	0	1133	2548	3681
5/9/2002	474	10	1624	186	956	130	0	0	3054	326	3380
5/10/2002	1234	293	0	0	786	70	1158	80	3178	443	3621
5/11/2002	1368	392	0	0	0	0	0	0	1368	392	1760
5/12/2002	0	0	0	0	0	0	0	0	0	0	0
5/13/2002	5042	707	0	0	0	0	0	0	5042	707	5749
5/14/2002	46	57	0	0	4549	151	4592	207	9187	415	9602
5/15/2002	181	40	0	0	0	0	0	0	181	40	221
5/16/2002	2144	463	0	0	0	0	0	0	2144	463	2607
5/17/2002	3966	412	0	0	0	0	0	0	3966	412	4378
5/18/2002	0	0	0	0	0	0	0	0	0	0	0
5/19/2002	0	0	0	0	0	0	0	0	0	0	0
5/20/2002	0	0	0	0	0	0	0	0	0	0	0
5/21/2002	0	0	0	0	0	0	0	0	0	0	0
5/22/2002	0	0	0	0	0	0	0	0	0	0	0
5/23/2002	2400	1339	0	0	0	0	0	0	2400	1339	3739
5/24/2002	19428	3607	0	0	0	0	0	0	19428	3607	23035
5/25/2002	5972	977	0	0	0	0	0	0	5972	977	6949
5/26/2002	2139	576	778	117	846	123	0	0	3763	816	4579
5/27/2002	0	0	2568	768	3429	1704	0	0	5997	2472	8469
5/28/2002	0	0	0	0	6556	4515	0	0	6556	4515	11071
5/29/2002	0	0	0	0	7385	2705	0	0	7385	2705	10090
5/30/2002	0	0	569	116	0	0	0	0	569	116	685
5/31/2002	185	67	980	328	12	5	86	36	1263	436	1699
6/1/2002	0	0	0	0	238	67	0	0	238	67	305
6/2/2002	224	61	0	0	0	0	0	0	224	61	285
6/3/2002	1813	431	0	0	0	0	0	0	1813	431	2244
6/4/2002	2035	385	0	0	0	0	0	0	2035	385	2420
6/5/2002	3788	458	0	0	0	0	0	0	3788	458	4246
6/6/2002	107	35	0	0	0	0	44	15	151	50	201
6/7/2002	0	0	0	0	0	0	96	15	96	15	111
Total	53679	12858	6519	1515	24757	9470	5976	353	90931	24196	115127

Table 12. Bird Counts in Various Weather Conditions, Fall

TracScan Target Counts, Fall Day											
Date	Clear		Fog		Mist		Rain		Total		Grand Total
	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	
9/3/2002	0	0	0	0	0	0	0	0	0	0	0
9/4/2002	6398	3758	408	194	1709	909	0	0	8515	4861	13376
9/5/2002	456	253	0	0	0	0	0	0	456	253	709
9/6/2002	0	0	0	0	0	0	0	0	0	0	0
9/7/2002	0	0	0	0	0	0	0	0	0	0	0
9/8/2002	1695	1959	153	206	0	0	0	0	1848	2165	4013
9/9/2002	9872	11145			0	0	0	0	9872	11145	21017
9/10/2002	4061	3164	1297	1194	1172	1090	0	0	6530	5448	11978
9/11/2002	8528	7429	0	0	0	0	907	261	9435	7690	17125
9/12/2002	6491	5315	0	0	0	0	0	0	6491	5315	11806
9/13/2002	9212	7058	0	0	0	0	0	0	9212	7058	16270
9/14/2002	14730	13939	0	0	1596	1676	0	0	16326	15615	31941
9/15/2002	3155	4306	0	0	255	294	179	182	3589	4782	8371
9/16/2002	292	234	0	0	2080	2478	1322	1429	3694	4141	7835
9/17/2002	11180	10977	0	0	0	0	0	0	11180	10977	22157
9/18/2002	11635	10852	0	0	221	174	0	0	11856	11026	22882
9/19/2002	14174	13161	0	0	192	117	0	0	14366	13278	27644
9/20/2002	0	0	0	0	0	0	0	0	0	0	0
9/21/2002	0	0	0	0	0	0	0	0	0	0	0
9/22/2002	0	0	0	0	0	0	0	0	0	0	0
9/23/2002	5647	3979	0	0	0	0	640	388	6287	4367	10654
9/24/2002	353	106	0	0	1599	552	5057	1376	7009	2034	9043
9/25/2002	8521	2635	0	0	0	0	0	0	8521	2635	11156
9/26/2002	7731	2007	0	0	0	0	413	91	8144	2098	10242
9/27/2002	4055	2665	525	381	773	190	504	60	5857	3296	9153
9/28/2002	8486	2811	0	0	0	0	0	0	8486	2811	11297
9/29/2002	11905	5125	0	0	0	0	0	0	11905	5125	17030
9/30/2002	4534	2741	0	0	0	0	0	0	4534	2741	7275
Total	153111	115619	2383	1975	9597	7480	9022	3787	174113	128861	302974

TracScan Target Counts, Fall Night											
Date	Clear		Fog		Mist		Rain		Total		Grand Total
	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	Slow	Fast	
9/3/2002	0	0	0	0	0	0	0	0	0	0	0
9/4/2002	1404	169	517	130	720	152	0	0	2641	451	3092
9/5/2002	2822	111	0	0	0	0	0	0	2822	111	2933
9/6/2002	0	0	0	0	0	0	0	0	0	0	0
9/7/2002	943	715	1600	856	2015	1147	0	0	4558	2718	7276
9/8/2002	3536	1629	5442	2789	934	465	0	0	9912	4883	14795
9/9/2002	17032	5226	0	0	0	0	0	0	17032	5226	22258
9/10/2002	23569	3090	5775	2066	0	0	0	0	29344	5156	34500
9/11/2002	1602	409	15809	4198	3138	564	171	23	20720	5194	25914
9/12/2002	17134	4975	0	0	0	0	0	0	17134	4975	22109
9/13/2002	16395	6156	0	0	0	0	0	0	16395	6156	22551
9/14/2002	5853	4734	0	0	0	0	0	0	5853	4734	10587
9/15/2002	1510	1084	0	0	0	0	575	329	2085	1413	3498
9/16/2002	259	195	2526	882	2974	1330	0	0	5759	2407	8166
9/17/2002	14631	3285	1754	798	14208	4767	0	0	30593	8850	39443
9/18/2002	6102	3460	2027	894	10690	4993	0	0	18819	9347	28166
9/19/2002	3699	2495	0	0	1805	1217	0	0	5504	3712	9216
9/20/2002	0	0	0	0	0	0	0	0	0	0	0
9/21/2002	0	0	0	0	0	0	0	0	0	0	0
9/22/2002	0	0	0	0	0	0	0	0	0	0	0
9/23/2002	13429	3427	0	0	0	0	0	0	13429	3427	16856
9/24/2002	10414	1697	0	0	0	0	329	51	10743	1748	12491
9/25/2002	11906	2039	0	0	0	0	0	0	11906	2039	13945
9/26/2002	3240	494	0	0	0	0	573	106	3813	600	4413
9/27/2002	760	264	87	33	669	162	544	192	2060	651	2711
9/28/2002	9061	3932	0	0	172	51	0	0	9233	3983	13216
9/29/2002	16703	2510	0	0	0	0	0	0	16703	2510	19213
9/30/2002	11581	3383	0	0	0	0	0	0	11581	3383	14964
Total	193585	55479	35537	12646	37325	14848	2192	701	268639	83674	352313

The process to compute heading distribution was:

1. Sort database into days, and also break into day and night.
2. Sort database into speed classes (slow < 27kts, fast \geq 27kts).
3. Process each speed class into heading bins
4. Process the night heading bins into one of two weather states, clear or non-clear
5. Remove all duplicates from each bin.

The heading distribution results are shown in **Figures 5 through 8**. They are plotted on a compass rose plot, one spoke for each of the 8 major cardinal directions. Each plot may have a different scale. Each figure presents the overall pattern, for fast or slow targets, in either spring or fall. Each figure also shows the daytime pattern, and the night-time pattern, subdivided into clear weather and non-clear weather behaviors.

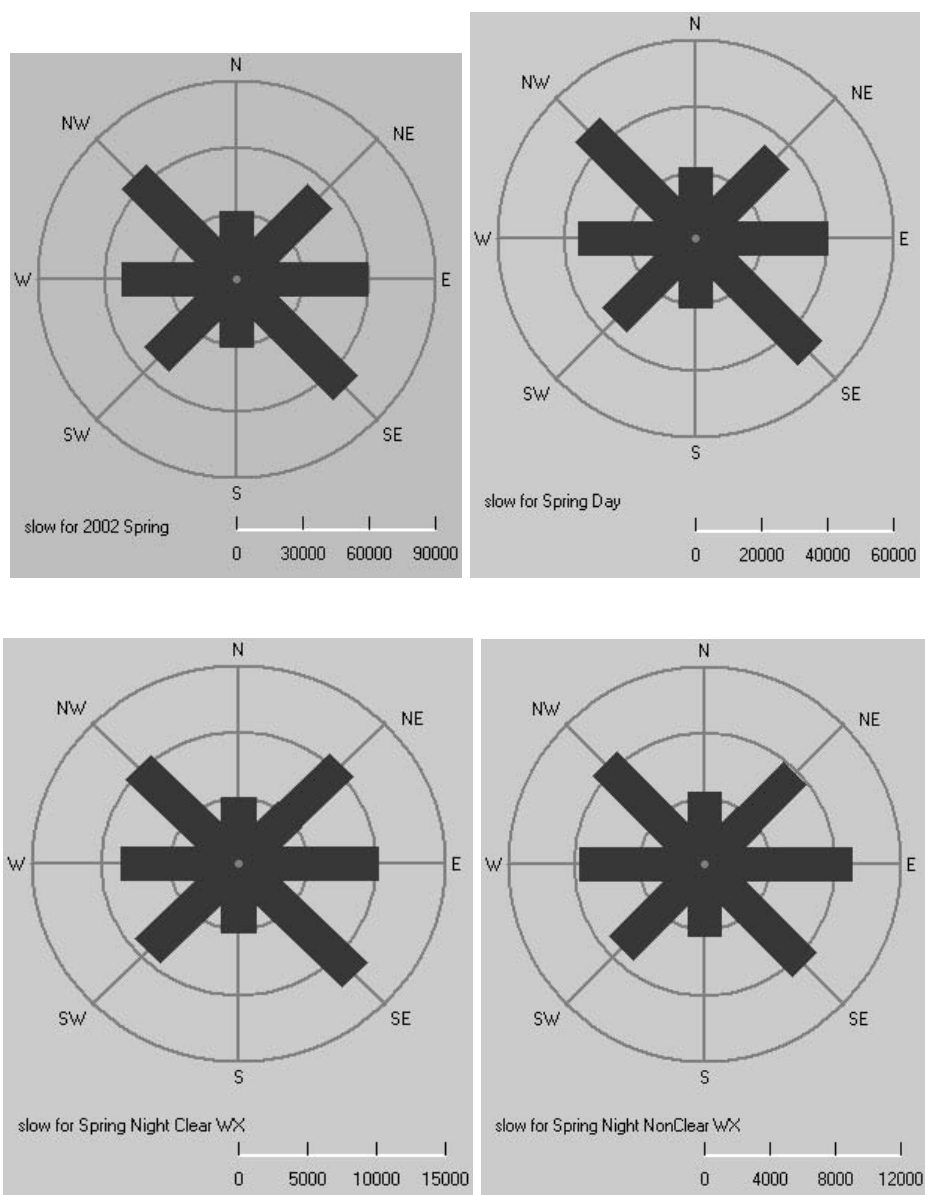


Figure 5. Slow Bird Heading Distribution, Spring.

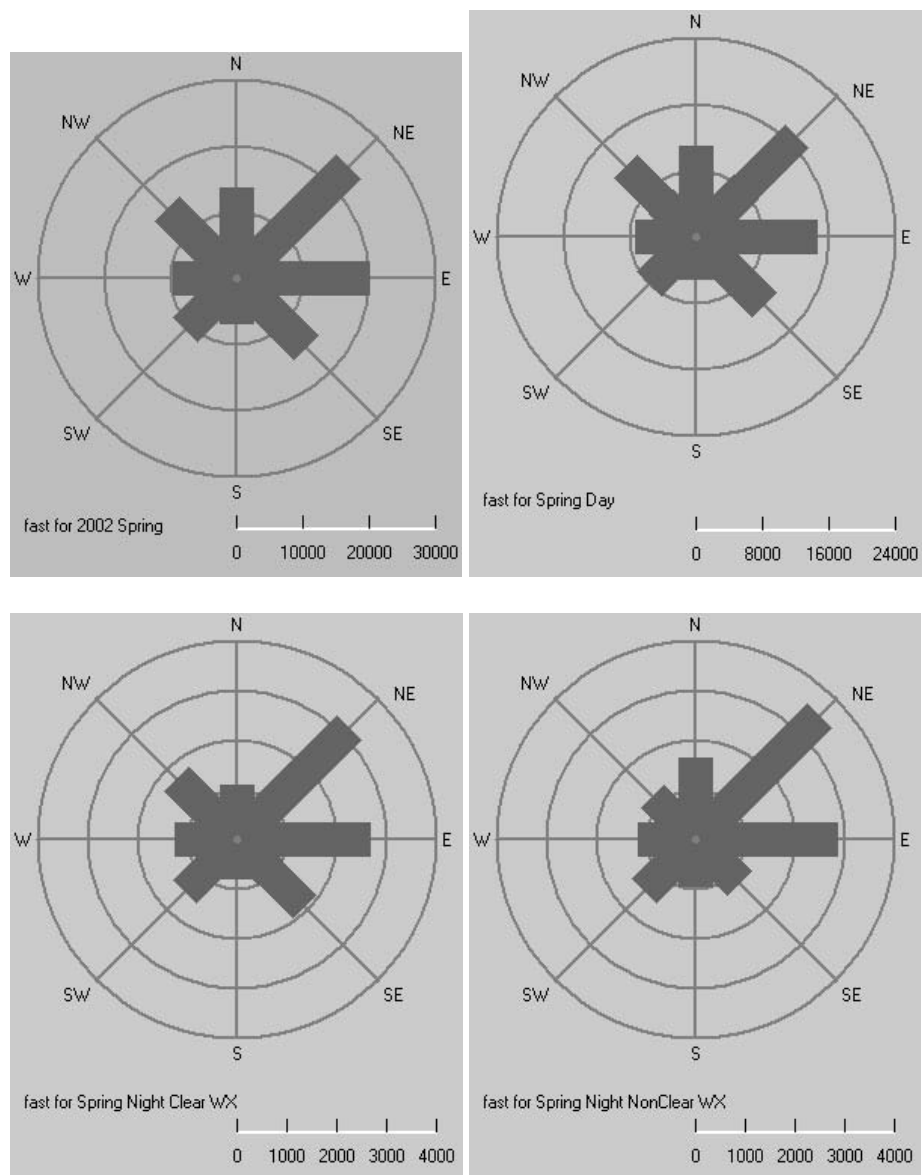


Figure 6. Fast Bird Heading Distribution, Spring

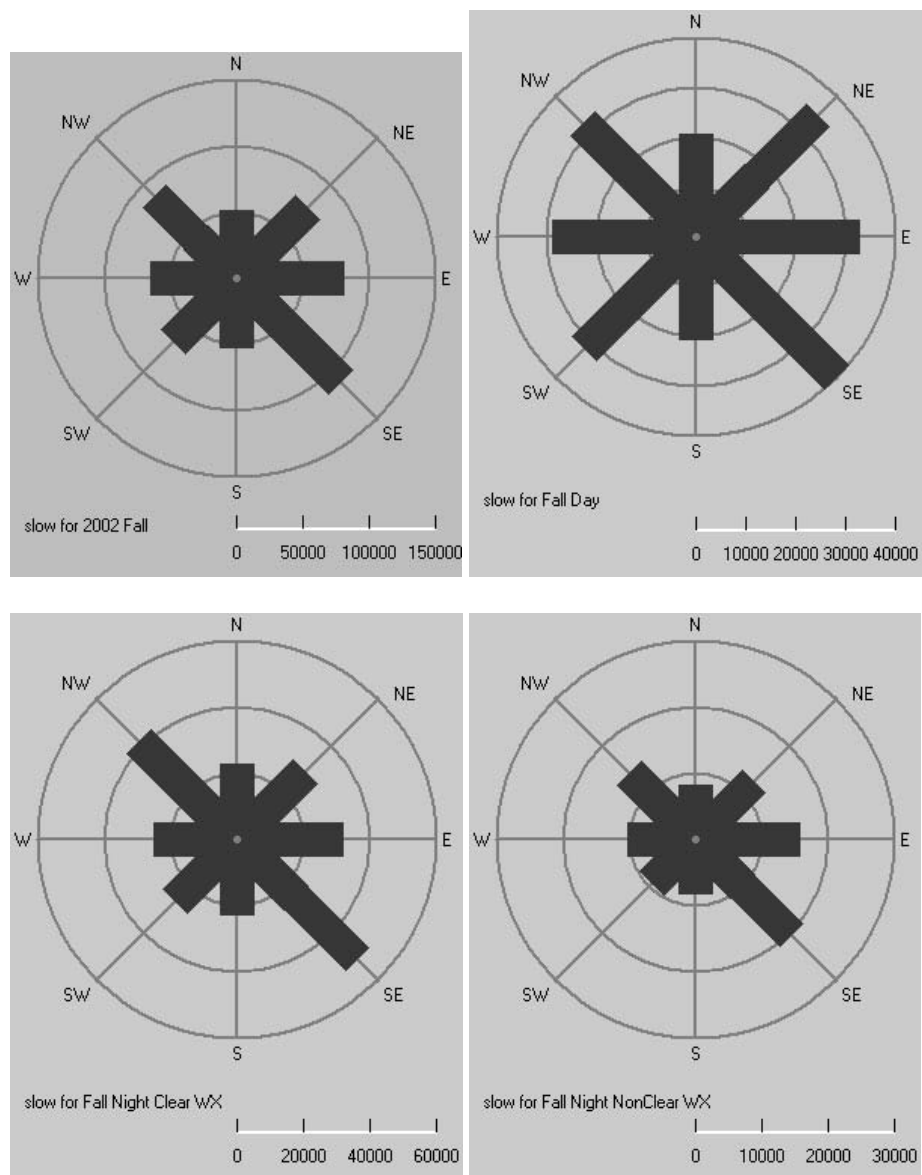


Figure 7. Slow Bird Heading Distribution, Fall

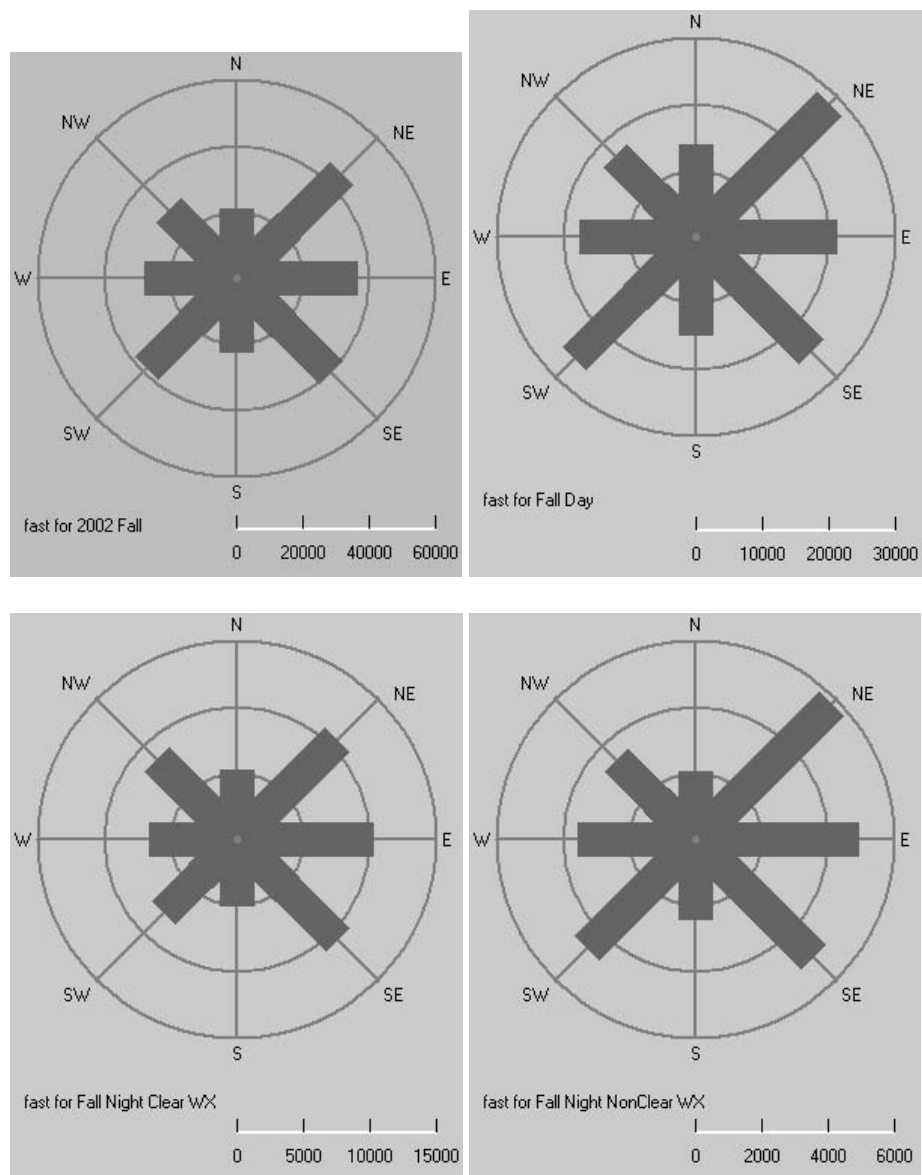


Figure 8. Fast Bird Heading Distribution, Fall

4.5 Field Observations

Field observations of birds in the Horseshoe Shoal area were made during both the spring and fall study periods, from the platform (spring), bluff (fall) and the boat (spring and fall). Tables 13 and 14 lists species representative of each size class that were observed during these periods.

Table 13. Bird Species Observed in Horseshoe Shoal During Spring Study Period

SPECIES	ADULT MASS (~G)	SIZE CLASS
Common Loon (<i>Gavia immer</i>)	4,100	L
Unknown Loon (<i>Gavia spp</i>)	1,400-5,400	L
Sooty Shearwater (<i>Puffinus griseus</i>)	780	M
Double-crested Cormorant (<i>Phalacrocorax auritus</i>)	1,700	L
Unknown Cormorant (<i>Phalacrocorax spp</i>)	1,700-3,000	L
Northern Gannet (<i>Morus bassanus</i>)	3,000	L
White-winged Scoter (<i>Melanitta fusca</i>)	1,670	L
Surf Scoter (<i>Melanitta perspicillata</i>)	950	L
Unknown Scoter (<i>Melanitta spp</i>)	950-1,670	L
Herring Gull (<i>Larus argentatus</i>)	1,150	L
Greater Black-backed Gull (<i>Larus marinus</i>)	1,650	L
Roseate Tern (<i>Sterna dougallii</i>)	110	M
Common Tern (<i>Sterna hirundo</i>)	120	M
Unknown Tern (<i>Sterna spp</i>)	42-660	S-M

Table 14. Bird Species Observed on Cape Poge and/or Nantucket Sound During Fall Study Period

SPECIES	ADULT MASS (~G)	SIZE CLASS
Sooty Shearwater (<i>Puffinus griseus</i>)	780	M
Double-crested Cormorant (<i>Phalacrocorax auritus</i>)	1,700	L
Unknown Cormorant (<i>Phalacrocorax spp</i>)	1,700-3,300	L
Great Blue Heron (<i>Ardea</i>)	2,400	L
Yellow-crowned Night-Heron (<i>Nyctanassa violacea</i>)	690	M
Mute Swan (<i>Cygnus olor</i>)	10,000	L
Snow Goose (<i>Chen caerulescens</i>)	2,420-3,400	L
American Black Duck (<i>Anas</i>)	1,200	L
Unknown small duck	400	M
White-winged Scoter (<i>Melanitta fusca</i>)	1,670	L
Surf Scoter (<i>Melanitta perspicillata</i>)	950	L
Osprey (<i>Pandion haliaetus</i>)	1,600	L
Northern Harrier (<i>Circus cyaneus</i>)	420	M
Sharp-shinned Hawk (<i>Accipiter striatus</i>)	140	M
Merlin (<i>Falco columbarius</i>)	190	M
Unknown Falcon (<i>Falco spp</i>)	117-1,400	M-L
Black-bellied Plover (<i>Pluvialis squatarola</i>)	240	M
Semipalmated Plover (<i>Charadrius semipalmatus</i>)	45	S
American Oystercatcher (<i>Haematopus palliatus</i>)	630	M
Greater Yellowlegs (<i>Tringa melanoleuca</i>)	160	M
Whimbrel (<i>Numenius phaeopus</i>)	390	M
Ruddy Turnstone (<i>Arenaria interpres</i>)	110	M
Sanderling (<i>Calidris alba</i>)	60	S
Laughing Gull (<i>Larus atricilla</i>)	320	M
Ring-billed Gull (<i>Larus delawarensis</i>)	520	M
Herring Gull (<i>Larus argentatus</i>)	1,150	L

SPECIES	ADULT MASS (~G)	SIZE CLASS
Greater Black-backed Gull (<i>Larus</i>)	1,650	L
Roseate Tern (<i>Sterna dougallii</i>)	110	M
Common Tern (<i>Sterna hirundo</i>)	120	M
Unknown Tern (<i>Sterna spp</i>)	42-660	S-M
Barn Owl (<i>Tyto alba</i>)	460	M
Unknown Crow (<i>Corvus spp</i>)	280-450	M
Tree Swallow (<i>Tachycineta bicolor</i>)	20	S
Belted Kingfisher (<i>Ceryle alcyon</i>)	150	M
Cedar Waxwing (<i>Bombycilla cedrorum</i>)	32	S
American Goldfinch (<i>Carduelis tristis</i>)	13	S